

WATTMETERS

FOR

DIRECT & ALTERNATING CURRENT MEASUREMENTS

FOR USE AT POWER FACTORS DOWN TO 50%, 20% and 5%

PORTABLE AND PANEL TYPE CASES



Models

DW
DLW
UNIVERSITY
VAW



Symbol of Quality

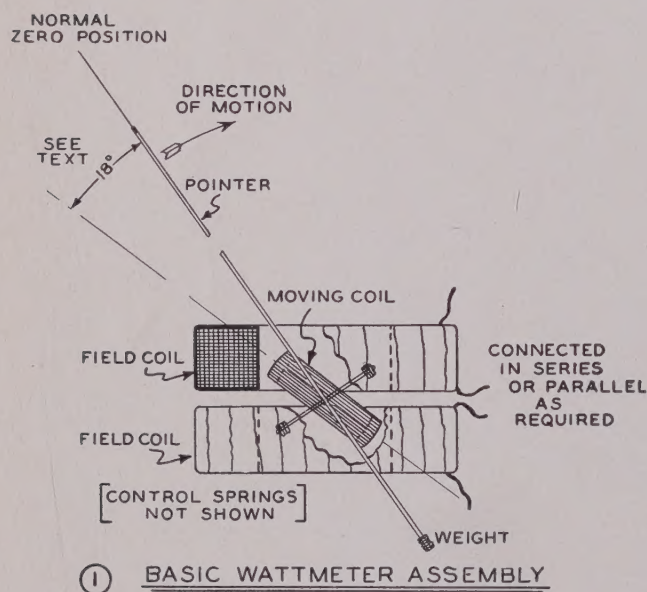
**SENSITIVE RESEARCH
INSTRUMENT CORPORATION**
NEW ROCHELLE, NEW YORK.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

LOW POWER FACTOR WATTMETERS

FOR USE ON D.C. AND A.C. UP TO 800 CYCLES

The measurement of electrical power is a somewhat difficult problem when alternating current power is considered. The simple relation of the power in watts being equal to the product of the voltage applied and the current drawn in amperes which is used for D.C. work, is no longer true as regards alternating current. It holds true only on an instantaneous basis, and may or may not be true as regards the RMS values of each, depending on the phase relation between voltage and current. The actual power becomes $E I \cos \theta$, with θ being the phase angle between voltage and current.



Fortunately for this situation we can use an instrument such as shown in Fig. 1 in which the magnetic field is established by two fields through which the load current is flowing. Rotating in that field is a moving coil with the usual restoring springs and pointer to indicate the torque

to which it may be subjected, and we have an answer to the power problem at frequencies up to 800 cycles. The torque of the moving coil will be proportional to the current in it multiplied by the current in the field coils, multiplied by the phase angle of the two currents. If we then add sufficient resistance in the moving coil circuit so that its current is proportional to the applied voltage, we have then satisfied the $E I \cos \theta$ formula.

The circuit of such an instrument is shown in Fig. 2. Several points about this circuit should be brought to mind in order to use this wattmeter under all conditions. In the first place, let us assume that the angle θ advances to 90 degrees. $\cos \theta$ then becomes 0 and at that point we see that we could draw an infinite current through the field coils or have an infinite voltage impressed across the potential circuit, and still there would be no power consumed. Obviously under these conditions the instrument would be burned out without the pointer moving at all.

It is this fact that the value of $\cos \theta$ can assume any value from 1 to 0 that makes it necessary to assign **LIMITING** values to the current capacity of the instrument which is dependent, NOT on the watt rating of the instrument, but upon the **CURRENT RATINGS** of the field coils. Instruments, in which the current capacity of the field coils is much greater than the normal current rating for 0 degrees phase angle (or 100% power factor as it is usually called), are listed as "Low Power Factor" type instruments. Our "REFERENCE STANDARD WATTMETERS" have a current rating of their field coils sufficient for use at power factors of 50% or more, while the "LOW POWER FACTOR" instruments can be used down to as low as 20% power factors with no danger of field coil damage. In certain special instruments this has been reduced to 5% P.F.

Another obvious point which is all too often overlooked is shown in Fig. 3. This shows the only two possible connections of the moving coil or potential circuit. It can be seen from the circuit that with the potential circuit connected to the load side of the field coil, the current being drawn to actuate the moving coil, is added to the load current and it is being measured by the instrument. On the other hand, with the potential circuit connected ahead of the field coil, the potential being used is greater than that actually applied to the load by the amount of the voltage drop in the field coil. In either case the instrument reads HIGH by the power lost in either its own potential or current circuit—NEVER by both, however.

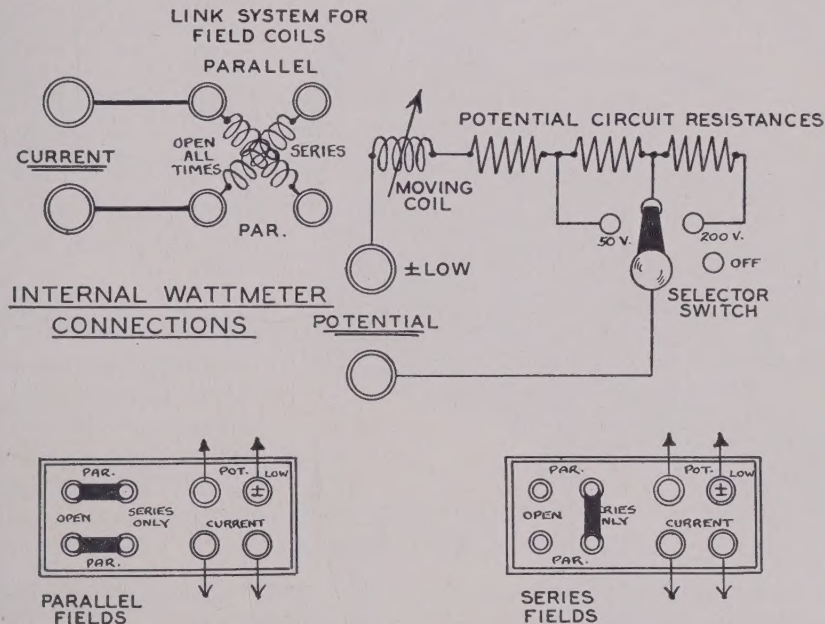
Each instrument has the potential circuit resistance indicated on the scale and the amount of error from the instrument power can be calculated and allowed for easily. The connection which gives the least power lost in the instrument should of course be used.

Using the "A" connection

$$\text{Actual watts} = \text{Wattmeter reading} - [I^2R (\text{fields}) + I^2R (\text{ammeter})]$$

Using the "B" connection

$$\text{Actual watts} = \text{Wattmeter reading} - \left[\frac{E^2}{R} (\text{potential circuit}) \right]$$

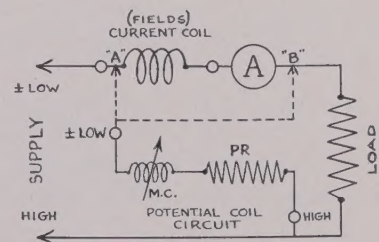


② CONNECTION PLATE ON INSTRUMENT CASE

FREQUENCY COMPENSATION

As seen in Fig 2 there could be appreciable inductance (that of the moving coil) in the potential circuit. The instrument could have a phase angle error which would increase with frequency and this is responsible for the frequency limitation given in the instrument listings. At these frequencies the phase angle error will ordinarily be less than one or two minutes, a negligible amount. If the instruments are required for readings at a given higher single frequency they can be compensated for that single frequency up to many times this normal value. They can also, with some greater difficulty be made, under certain limitations, to have a flat frequency characteristic. Correspondence on such instruments is invited.

One of the very desirable characteristics of the SENSITIVE RESEARCH Wattmeters is the wide-open, even spacing of the scale "divisions." This scale spacing which makes

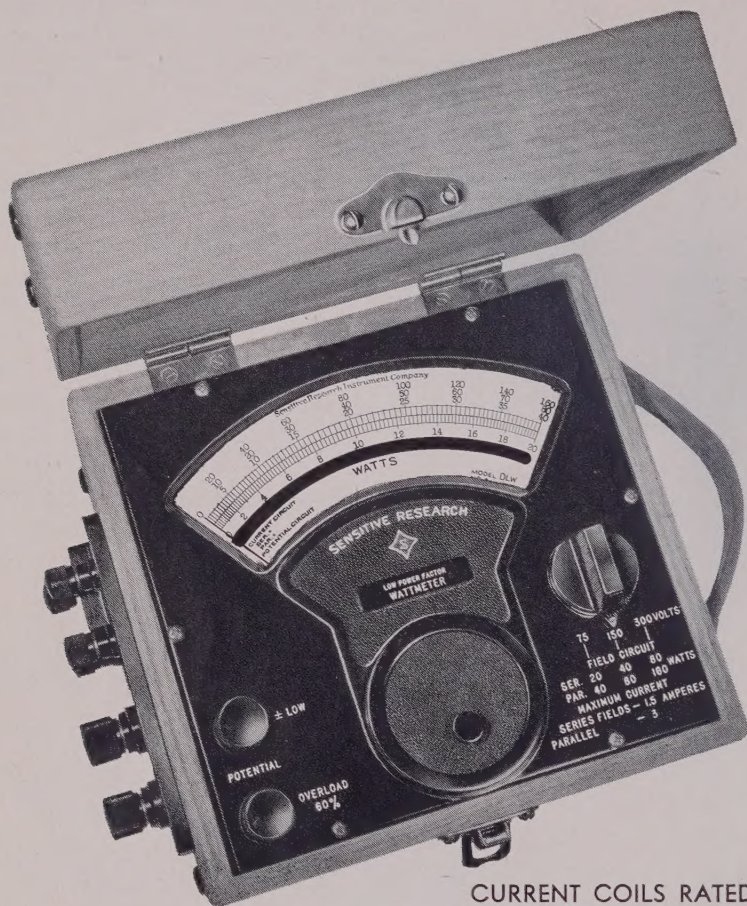


FUNDAMENTAL CIRCUIT
FIGURE 3

for the excellent "readability" of our Wattmeter consists of specially formed field coils which almost totally enclose the moving system. It will be noticed from figure (1) that the pointer is set an angle of approximately 18° in advance of the plane of the moving coil. This allows the approximately 75° of pointer travel to operate over a substantially linear range of movement. This is just one

LOW POWER FACTOR WATTMETERS

MODEL DLW



CURRENT COILS RATED
FOR USE AT P.F. DOWN TO 20%

of the many small but important details which serve to produce the high level of "customer satisfaction" which is a built-in feature of every SENSITIVE RESEARCH instrument.

"SENSITIVE RESEARCH" has been building precision wattmeters for the past 29 years.

The instruments described in the following pages, represent the "last word" in instrument design and operating technique. They are supplied with long, easily read, non-warping scales—positive click position selector switches—

are shielded magnetically and electrostatically, and are rapid in indication.

Our DW and DLW wattmeters are encased in a walnut or formica case with a moulded black bakelite panel having non-removable engraving. For panel mounting, we suggest our Models EW-5 or EW-7 deep case, both of which have a 5.2" scale. See page 87. The moving coil swings on spring shock mounted sapphire jewels with "tuned" pointers that are completely free from resonant vibration troubles over the frequency range of the instrument. For the very sensitive ranges, we use our diamond pivots and shock mounted jewels.

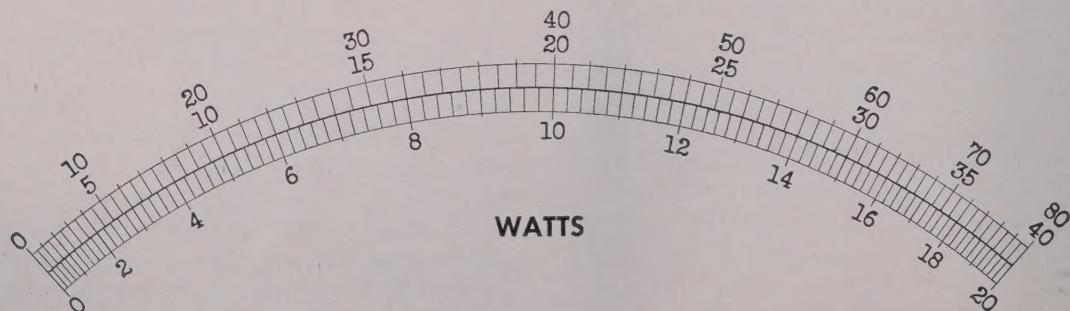
ACCURACY—	.5 of 1%
SCALE—	5.2"
FREQUENCY—	D.C. & 25 - 500 cy.
SIZE—	8"x7½"x6"
WEIGHT—	7 lbs.
TYPE—	Dynamometer

HORIZONTAL USE ONLY

FORMICA CASES are available for all portable instruments normally encased in wood. Such cases, we believe, are the finest in "the state of the art." They are structurally strong, dimensionally stable, and extremely resistant to deterioration from rough handling or adverse environmental conditions. In addition, they are furnished with a fitted panel gasket, which serves as an effective dust seal. The formica case itself is a good humidity BARRIER. The finish of any formica case will be like "new" even though subjected to the severest usage.

Add \$15.00 to any list price, if "formica case" is ordered.

"DIAMOND PIVOTS" and shock mounted sapphire jewels are available for all wattmeters listed in this section (whether in portable or edgewise panel case). Where this assembly is not noted as standard, specify "Diamond Pivots" and add \$30.00 to listed price.



LOW POWER FACTOR WATTMETERS

The size of a wattmeter CANNOT be chosen solely by the number of watts to be measured. It must be fixed by the current and voltage of the circuit, irrespective of power, since the wattmeter coils will only stand a certain current before burning out. If the power factor is low, the watts will be low, despite the high volts and amperes. The only solution is to use a sensitive wattmeter DESIGNED for low power factor work. Such a wattmeter has a watt rating which is but a fraction of its volt-ampere rating. All SENSITIVE RESEARCH wattmeters can be used down to 50% and some special instruments as low as 5% power factor. This means the use of heavy wire (and few turns) in the field circuit, with a resultant loss of torque, and calls for a high degree of engineering and craftsmanship in the design and construction of such instruments.

PHASE ANGLE

Phase angle can be considered negligible up to 800 cycles because the time constant of our own unusual design is so small. This is accomplished by advanced coil designs that have an unusually high ratio of non-inductive series resistance in the potential coil circuit compared to the inductance.

SPECIAL LOW POWER FACTOR WATTMETERS

MODEL DLW

Fitted with new Diamond Pivots and shock mounted jewels thus reducing the friction to a completely negligible level.

There are so many, many possible combinations of wattmeters that it would be impractical to attempt to list them all. We therefore are listing below some representative combinations. Wattmeters with ranges in the vicinity, can be supplied at the same cost as those listed below. All instruments have double current ranges (using either series or parallel fields). The current coils are changed by convenient links and the voltage ranges are controlled by a rotary switch moulded into the panel.

**TYPICAL UNUSUAL WATTMETERS

Full Scale Watts	NORMAL (Unity P. F.) FIELD CURRENT		MAXIMUM (20% P. F.) FIELD CURRENT		Volts	Code	Price
	Series	Parallel	Series	Parallel		Word	
.05/1	.0025 A.	.0050 A.	.0125 A.	.025 A.	20	WALAM	\$410.00
.2/4/.8/1.6	.026 A.	.0533 A.	.133 A.	.266 A.	7.5/15/30	WALEK	385.00
.2/4/.8/1.6	.040 A.	.080 A.	.200 A.	.400 A.	5/10/20	WALIS	385.00
.3/6/1.2	.075 A.	.150 A.	.375 A.	.750 A.	4/8	WALOB	395.00
1/2	.500 A.	1.00 A.	2.5 A.	5.0 A.	2	WALUT	400.00
2.5/5/10	.100 A.	.200 A.	.50 A.	1.00 A.	25/50	WALLO	350.00
5/10	.50 Amp.	1.00 Amp.	2.5 Amp.	5.00 Amp.	10	WALLY	385.00
7.5/15	.50 Amp.	1.00 Amp.	2.5 Amp.	5.00 Amp.	15	WALLA	380.00
10/20	.40 Amp.	.80 Amp.	2 Amp.	4.00 Amp.	25	WALOO	380.00
* 10 Watts only	(.5 to 2 Amps)		(4 Amperes)		5/10/20	WALEA	385.00

*Even if the watt ranges you desire seem to be impractical to build—please write us anyway!

**The above instruments are special designs and do not in all cases meet standard characteristics as to frequency, potential circuit load, etc. Correspondence invited.

DIRECT CURRENT MEASUREMENT

To obtain the greatest accuracy on direct current, the "mean" of reversed readings should be taken. This procedure will eliminate any residual magnetism in the shielding that may have been caused by very strong external magnetic fields.

SPECIAL FREQUENCY RANGES

On special order and in certain cases wattmeters can be supplied for use up to 2500 cycles. Our wattmeters can be used down to frequencies of 15 cycles if required. Correspondence invited.

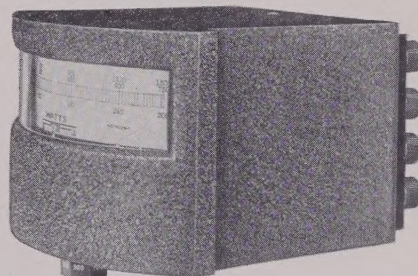
VOLTAGE MULTIPLIERS

Voltage multipliers can be supplied for any of our wattmeters to increase the watt ranges. Such multipliers are always connected in series with the high side potential binding post.

CAUTION

Always connect the "± Low" binding post of the potential circuit to the same point in the circuit as the "± Low" current coil. This connection will eliminate the errors that might be due to any electrostatic action between the current and potential coil.

On wattmeters mounted in our EW-5 panel case, only the voltage ranges can be switch controlled. The current circuit must be switched by external switches. This can be supplied by us at an additional cost on request.



FOR EW-5 (DEEP) PANEL MOUNTING CASE

See pages 86 and 87.
ADD \$25.00 TO PRICES

SINGLE PHASE WATTMETERS

MODEL DLW

ACCURACY—	.5 of 1%
SCALE—	5.2"
FREQUENCY—	See below
SIZE—	8"x7 1/2"x6"
WEIGHT—	7 lbs.
TYPE—	Dynamometer

CURRENT COILS RATED FOR USE AT
LOW POWER FACTORS DOWN TO 20%

CAN BE USED ON D.C. AND A.C. UP TO
500 CYCLES WITHOUT CORRECTIONS

HORIZONTAL

USE ONLY

For Model EW-5 deep (5.2" scale) panel mounting case, add \$25.00 to prices listed below. See pages 86 and 87 for specifications.

The wattmeters listed below, are for use on power factors down to 20%. In special cases we can supply them for use on power factors down to 5% or at frequencies up to 2500 cycles. Correspondence invited.

Due to our large experience with precision wattmeters over the past 29 years, we invite inquiries on special wattmeter problems.

THREE RANGES

FULL SCALE WATTS		NORMAL (Unity P. F.) FIELD CURRENT		MAXIMUM (20% P. F.) FIELD CURRENT		(OVERLOAD 60%) VOLTS		Code Word	Price
Low Volts	High Volts	Series	Parallel	Series	Parallel	Low	High		
*.2/.4	.4/.8	.00266 A.	.00532 A.	.0133 A.	.0266 A.	75	150	WARIK	\$270.00
**3/.6	.6/1.2	.004 A.	.008 A.	.02 A.	.04 A.	75	150	WASOL	270.00
.5/1.0	1/2	.0066 A.	.0132 A.	.033 A.	.066 A.	75	150	WAKUP	270.00
1.5/3	3/6	.02 A.	.04 A.	.10 A.	.20 A.	75	150	WAMOS	270.00
†5/10	10/20	.066 A.	.132 A.	.33 A.	.66 A.	75	150	WAKOR	310.00
7.5/15	15/30	.1 A.	.2 A.	.5 A.	1.0 A.	75	150	WACOT	270.00
10/20	20/40	.133 A.	.266 A.	.666 A.	1.333 A.	75	150	WAROT	270.00
15/30	30/60	.2 A.	.4 A.	1.0 A.	2.0 A.	75	150	WACUM	270.00
20/40	40/80	.266 A.	.532 A.	1.33 A.	2.66 A.	75	150	WAPOT	270.00
37.5/75	75/150	.5 A.	1.0 A.	2.5 A.	5.0 A.	75	150	WAKER	270.00
75/150	150/300	1.0 A.	2.0 A.	5 A.	10 A.	75	150	WAKIT	275.00
150/300	300/600	2 A.	4 A.	10 A.	20 A.	75	150	WARUS	290.00
300/600	600/1200	4 A.	8 A.	20 A.	40 A.	75	150	WAAST	300.00
750/1500	1.5/3.0 k.w.	10 A.	20 A.	50 A.	100 A.	75	150	WAOFT	310.00

Any of the above ranges available with the voltage increased to 110-220 volts at no additional cost, with the exception of the 5% P.F. instruments. Watt ranges will remain the same, but current ranges will change. Use the above code word, adding the letter "s" — except codes WARIK and WASOL.

†For use down to 5% power factor for condenser tests at 75 and 150 volts, 60 cycles only. DIAMOND PIVOTS AND SHOCK MOUNTED JEWELS USED ON THIS INSTRUMENT.

Potential circuits have a resistance of from 100 to 350 ohms per volt.
The low watt instruments usually have a volt circuit requiring 10 milliamperes.

FOUR RANGE WATTMETERS

FULL SCALE WATTS			UNITY P. F. FIELD CURRENT		20% P. F. FIELD CURRENT		(OVERLOAD 60%) VOLTS			Code Word	Price
Low Volts	Medium Volts	High Volts	Series	Parallel	Series	Parallel	Low	Medium	High		
*.2/.4	.4/.8	.8/1.6	.00266 A.	.0532 A.	.0133 A.	.0266 A.	75	150	300	WATAK	\$285.00
**3/.6	.6/1.2	1.2/2.4	.004 A.	.008 A.	.02 A.	.04 A.	75	150	300	WATER	285.00
.5/1.0	1.0/2.0	2.0/4.0	.0066 A.	.013 A.	.0333 A.	.0666 A.	75	150	300	WATIL	285.00
1.5/3	3/6	6/12	.02 A.	.04 A.	.1 A.	.2 A.	75	150	300	WATOS	285.00
5/10	10/20	20/40	.0666 A.	.133 A.	.333 A.	.666 A.	75	150	300	WATUF	285.00
15/30	30/60	60/120	.2 A.	.4 A.	1 A.	2 A.	75	150	300	WATYI	285.00
††20/40	40/80	80/160	.266 A.	.532 A.	1.33 A.	2.66 A.	75	150	300	WATKO	285.00
37.5/75	75/150	150/300	.5 A.	1 A.	2.5 A.	5.0 A.	75	150	300	WATSA	290.00
75/150	150/300	300/600	1 A.	2 A.	5 A.	10 A.	75	150	300	WATTI	295.00
150/300	300/600	600/1.2 k.w.	2 A.	4 A.	10 A.	20 A.	75	150	300	WATBA	305.00
300/600	600/1.2	1.2/2.4 k.w.	4 A.	8 A.	20 A.	40 A.	75	150	300	WATFO	322.00

Any of the above ranges available with the voltage increased to 110-220-440 volts at no additional cost. Use the above code word adding the letter "s" — except codes WATAK and WATER. Watt ranges will remain the same but current ranges will change.

††Designed specifically to be the STANDARD WATTMETER in fluorescent lamp measurements.

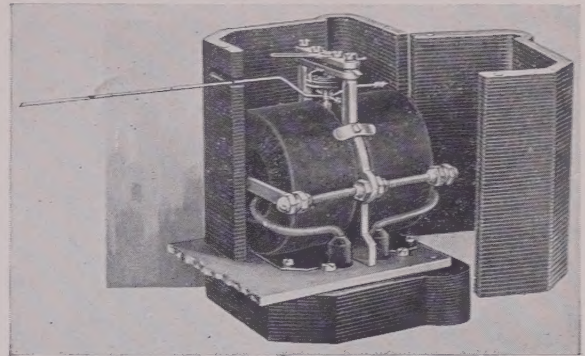
*For D.C. and 25-125 cycle use only.

**For D.C. and 25-250 cycle use only.

REFERENCE STANDARD WATTMETERS

ACCURACY—	.25 of 1%
SCALE—	6.3"
FREQUENCY—	To 800 cycles
SIZE—	8"x7½"x6"
WEIGHT—	7 lbs.
TYPE—	Dynamometer

MODEL DW



MOVEMENT AND MAGNETIC SHIELDING

ACCURACY .25% OF 1%

FOR USE ON
D.C. OR A.C.

UP TO 800 CYCLES

CURRENT COILS RATED FOR USE AT
POWER FACTORS DOWN TO 50%

In certain cases Reference Standard Wattmeters can be compensated for use above 1000 cycles. Correspondence invited.

HORIZONTAL USE ONLY

For panel mounting cases models
EW-5 (Add \$25 to listed prices),
or EW-7 (Add \$30), see pages 86
and 87 for specifications.

SHIELDING:

The moving coil, field winding and essential parts are completely enclosed in a soft iron laminated box, having approximately 100 laminations, each lamination being electrically insulated from any other. This shielding system effectually shields the coils from external magnetic fields and electrostatic charges.

All our Wattmeter movements are very effectively damped by double vane air dampers, moving in effectively airtight semi-circular chambers. They are so designed that they do not materially add to the moment of inertia or appreciable weight to the moving system.

THREE RANGE

FULL SCALE WATTS		NORMAL (Unity P. F.) FIELD CURRENT		MAXIMUM (50% P. F.) FIELD CURRENT		(OVERLOAD 60%) VOLTS		Code Word	Price
Low Volts	High Volts	Series	Parallel	Series	Parallel	Low	High		
5/10	10/20	.05 A.	.1 A.	.1 A.	.2 A.	100	200	WALER	\$265.00
7.5/15	15/30	.075	.15	.15	.3	100	200	WABCL	265.00
15/30	30/60	.15	.30	.3	.6	100	200	WAMIS	265.00
25/50	50/100	.25	.50	.5	1.0	100	200	WANOT	265.00
37.5/75	75/150	.375	.75	.75	1.5	100	200	WYFAT	265.00
75/150	150/300	.75	1.5	1.5	3.0	100	200	WASUL	265.00
125/250	250/500	1.25	2.5	2.5	5.0	100	200	WARAB	265.00
150/300	300/600	1.5	3	3	6	100	200	WHACK	270.00
250/500	500/1000	2.5	5	5	10	100	200	WASED	275.00
300/600	600/1.2 k.w.	3	6	6	12	100	200	WAHLN	275.00
500/1000	1.0/2.0 k.w.	5	10	10	20	100	200	WARAC	285.00

Potential circuits vary from 100 to 333 ohms per volt.

The lower watt instruments require a 10 milliamperes potential circuit current.

FOUR RANGE WATTMETER

FULL SCALE WATTS			NORMAL FIELD CURRENT		MAXIMUM FIELD CURRENT		(OVERLOAD 60%) VOLTS			Code Word	Price
Low Volts	Medium Volts	High Volts					Low	Medium	High		
15/30	30/60	60/120	.3 A.	.6 A.	.6 A.	1.2 A.	50	100	200	WEAPA	\$280.00
25/50	50/100	100/200	.5	1.0	1.0	2.0	50	100	200	WEALM	280.00
50/100	100/200	200/400	1	2	2	4	50	100	200	WEAZO	280.00
75/150	150/300	300/600	1.5	3	3	6	50	100	200	WEAEN	285.00
125/250	250/500	500/1000	2.5	5	5	10	50	100	200	WEAFE	288.00
250/500	500/1000	1000/2000	5	10	10	20	50	100	200	WEAGZ	298.00

NOTE:—All the above ranges can be supplied but with the voltages
increased to 110 220 440

Watt ranges will remain the same but current ranges will change.

Use the
above code
word adding
the letter
"S"
Prices
same
as
above
ranges

*SPECIAL WATTMETER FOR HIGH VOLTAGE TESTS

	Normal	Maximum	Has External Multiplier	
50/100/200/400/800 Watts	.066 A.	.133 A.	.133 A. .266 A.	750/1500/3000/6000 Volts.....STERIL 365.00

Designed for testing cathode discharge lamps which operate at high voltage and low currents usually from a high reactance transformer.

*The Wattmeter has low resistance fields and a very high impedance potential circuit. (770 ohms per volt!)

SINGLE PHASE LOW POWER FACTOR WATTMETERS

UNIVERSITY MODEL



ACCURACY—	.75 of 1%
SCALE—	4"
FREQUENCY—	D.C. up to 500 cycles
SIZE—	5¼"x5"x4⅞"
WEIGHT—	4½ lbs.
TYPE—	Dynamometer

HORIZONTAL USE ONLY

CURRENT COILS RATED FOR USE AT
POWER FACTORS DOWN TO 20%

FOR USE ON D.C. AND A.C. UP TO 500 CYCLES

These smaller dynamometer wattmeters were designed particularly for use on low power factor circuits, at moderate cost.

All instruments have double current and double voltage ranges. The current coils are changed by convenient links and the voltage ranges are controlled by a rotary switch moulded into the bakelite panel.

An ordinary wattmeter, which can be used down to 50% P.F. might have its current coils burnt out by a read-

ing which would be *WITHIN* the watt range of the instrument, but whose P.F. might be so low as to cause a large "out of phase" current to flow through the current coils.

The only solution is to use a wattmeter *DESIGNED* for low P.F. work. Such a wattmeter has a watt scale which is but a fraction of its volt-ampere rating.

These wattmeters are mounted in a black moulded bakelite case with non-removable binding posts. They have easily read, non-warping scales, and the movement rotates on spring shock mounted sapphire jewels.

Our potential circuits of these instruments require very low currents due to their advanced design. They vary from 66 to 333 ohms per volt.

UNIVERSITY Model WATTMETERS can not be supplied for panel mounting.

FULL SCALE WATTS		UNITY P. F. FIELD CURRENT		MAXIMUM (20% P. F.) FIELD CURRENT		(OVERLOAD 60%) VOLTS		Code Word	Price
Low Volts	High Volts	Series	Parallel	Series	Parallel	Low	High		
*1.2/4	.4/.8	.00266 A.	.00532 A.	.0133 A.	.0266 A.	75	150	UWAMOS	\$180.00
†1.3/6	.6/1.2	.004 A.	.008 A.	.02 A.	.04 A.	75	150	UWAPOT	180.00
.5/1	1/2	.0066 A.	.0132 A.	.033 A.	.066 A.	75	150	UWARUV	180.00
1.5/3	3/6	.02 A.	.04 A.	.10 A.	.20 A.	75	150	UWATEX	180.00
**5/10	10/20	.066 A.	.132 A.	1.33 A.	2.66 A.	75	150	UWAVIZ	220.00
7.5/15	15/30	.1 A.	.2 A.	.5 A.	1.0 A.	75	150	UWAWOB	180.00
10/20	20/40	.133 A.	.266 A.	.666 A.	1.333 A.	75	150	UWAXUD	180.00
15/30	30/60	.2 A.	.4 A.	1.0 A.	2.0 A.	75	150	UWABAF	180.00
37.5/75	75/150	.5 A.	1.0 A.	2.5 A.	5.0 A.	75	150	UWACEG	180.00
75/150	150/300	1.0 A.	2.0 A.	5 A.	10 A.	75	150	UWADIK	180.00
150/300	300/600	2 A.	4 A.	10 A.	20 A.	75	150	UWAFQJ	200.00
300/600	600/1200	4 A.	8 A.	20 A.	40 A.	75	150	UWAGUK	205.00
750/1500	1.5/3 k.w.	.10 A.	20 A.	.50 A.	100 A.	75	150	UWAHAL	205.00

*This range wattmeter is particularly adapted for cable and general insulation testing with or without potential transformers.

**For use down to 5% power factor for condenser testing. Supplied with diamond pivots and shock mounted jewels.

Any of the above ranges available with the voltage increased to 110-220 volts at no additional cost, with the exception of the codes UWAMOS and UWAPOT. Watt ranges will remain the same but current ranges will change.

†For D.C. and 25-125 cycle use only.

††For D.C. and 25-250 cycle use only.

GENERAL TESTING SINGLE PHASE WATTMETERS

UNIVERSITY MODEL

This instrument is similar in appearance as well as internal design to its companion UNIVERSITY low power factor model with its highly polished moulded black case and chrome plated metal fittings.

It is designed for use where a rugged, portable, short period wattmeter is desired for the shop, field or laboratory as a general testing instrument.

It can be used equally as well on D.C. or single phase A.C. up to 800 cycles. Besides their inherent built-in accuracy, typical of all SENSITIVE RESEARCH instruments, they are capable of withstanding large momentary overloads. They are, therefore, economical of maintenance, an item of importance to any user.

These wattmeters are supplied with links for connecting the current coils in series or parallel. Two and three voltage ranges are supplied making the instrument very flexible.

These wattmeters are very moderately priced and are ideal for engineering student use as well as for precision

CURRENT COILS RATED FOR USE AT
POWER FACTORS DOWN TO 50%

ACCURACY—	.5 of 1%
SCALE —	4"
FREQUENCY—	D.C. to 800 cycles
SIZE —	5¼"x5"x4¾"
WEIGHT —	4 lbs.
TYPE —	Dynamometer

HORIZONTAL USE ONLY

work in laboratories operating on modest budgets. They are unreservedly guaranteed, and their action and accuracy will remain long after their purchase price has been forgotten.

The potential circuits of these instruments operate on low currents which means low internal losses. The "ohms per volt" varies from 66 to 333 ohms for volt.

FULL SCALE WATTS		NORMAL (Unity P. F.) FIELD CURRENT		MAXIMUM (50% P. F.) FIELD CURRENT		OVERLOAD (60%) VOLTS		Code Word	Price
Low Volts	High Volts	Series	Parallel	Series	Parallel	Low	High		
5/10	10/20	.05 Amp.	.1 Amp.	.1 Amp.	.2 Amp.	100	200	UWANAB	\$170.00
7.5/15	15/30	.075 Amp.	.15 Amp.	.15 Amp.	.3 Amp.	100	200	UWALOP	170.00
15/30	30/60	.15 Amp.	.3 Amp.	.3 Amp.	.6 Amp.	100	200	UWARIC	170.00
25/50	50/100	.25 Amp.	.5 Amp.	.5 Amp.	1.0 Amp.	100	200	UWAPEB	170.00
37.5/75	75/150	.375 Amp.	.75 Amp.	.75 Amp.	1.5 Amp.	100	200	UWASOD	170.00
75/150	150/300	.75 Amp.	1.5 Amp.	1.5 Amp.	3.0 Amp.	100	200	UWATUF	170.00
125/250	250/500	1.25 Amp.	2.5 Amp.	2.5 Amp.	5.0 Amp.	100	200	UWAVAG	170.00
150/300	300/600	1.5 Amp.	3.0 Amp.	3.0 Amp.	6.0 Amp.	100	200	UWAVEG	170.00
250/500	500/1000	2.5 Amp.	5.0 Amp.	5.0 Amp.	10.0 Amp.	100	200	UWABIK	175.00
300/600	600/1200	3.0 Amp.	6.0 Amp.	6.0 Amp.	12.0 Amp.	100	200	UWACOL	175.00
500/1000	1000/2000	5.0 Amp.	10.0 Amp.	10.0 Amp.	20.0 Amp.	100	200	UWADUM	175.00

FULL SCALE WATTS		NORMAL Field Current		MAXIMUM Field Current		VOLTS		Code Word	Price
Low Volts	Medium Volts	High Volts				Low	Medium High		
15/30	30/60	60/120	.3	.6	.6	50	100 200	UWAKAY	\$195.00
25/50	50/100	100/200	.5	1.0	1.0	50	100 200	UWABAT	195.00
50/100	100/200	200/400	1.0	2.0	2.0	50	100 200	UWACES	195.00
75/150	150/300	300/600	1.5	3.0	3.0	50	100 200	UWADIR	198.00
125/250	250/500	500/1000	2.5	5.0	5.0	50	100 200	UWAFOV	198.00
250/500	500/1000	1000/2000	5.0	10.0	10.0	50	100 200	UWAGUX	198.00

NOTE:—ALL the above watt ranges available, only the voltages are increased to 110, 220 and 440 volts at the same listed prices.
Add the letter "S" to the code word for the above voltage.

VOLT-AMP-WATTMETERS

MODEL VAW VOLT - AMP - WATTMETER FOR USE FROM 50 TO 800 CYCLES

The instrument described in the following pages is one of the progressive developments to come from the laboratories of "SENSITIVE RESEARCH" after a year of actual customer field tests (May 1948).

It is said that a "good engineer" must do for a dollar what the usual person would do for two. Progressive electrical laboratories and engineers are always interested in new ways to reduce costs.

Our alternating current VOLT-AMP-WATTMETER will materially lower laboratory investment and time costs.

We have in this VOLT-AMP-WATTMETER an essential laboratory instrument. Its wide frequency spread of 50 to 800* cycles enables the user to measure accurately the VOLTS, AMPERES and WATTS usually encountered in most circuits.

This really new instrument contains **three** distinct instruments in one.

It is a VOLTMETER, an AMMETER and a WATTMETER

It reduces "set up" time because of its internally connected circuits.

It is simple in operation.

It is accurate over all its wide range of measurements in VOLTS, AMPERES and WATTS at frequencies of 50 to 800 cycles*.

It is fast in indication.

As a VOLTMETER

Full scale ranges 0 - 25/50/100/200/500 volts

As an AMMETER

Full scale ranges 0 - .5/1/5/10 Amperes

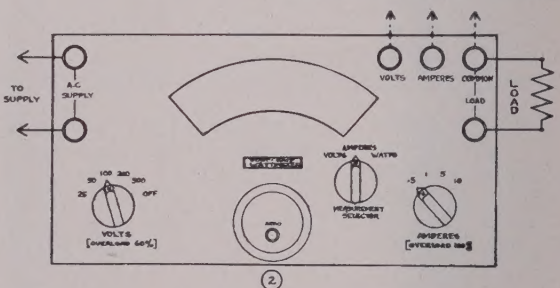
As a WATTMETER

It is a compensated Wattmeter with a linear scale

Having a total of 12 ranges as follows:

0 - 12.5/25/50/100/125/200/250/500/1000/2000/2500/5000 Watts

Connections for use as a separate ammeter or voltmeter



*See page 125 for 50 - 133 cycle and 50 - 800 cycle combinations.

It accomplishes the above measurements without changing the connections. All necessary switching is internally controlled by positive detent selector switches. It is extremely simple to make external connections to measure the VOLTS applied to the load, the load AMPERES and the WATTS. (See Figure 2.)

The instrument is supplied in a walnut case 13 $\frac{3}{4}$ " x 7 $\frac{1}{2}$ " x 6 $\frac{1}{2}$ " with a substantial leather carrying strap and brass chrome plated hardware. Its moulded bakelite panel is very legibly engraved and its binding posts have non removable heads to prevent their loss.

The indicating instrument is an accurate, rugged magnetically shielded dynamometer. The current transformer is shielded and is designed for 50-800 cycle use.

This new VOLT-AMP-WATTMETER is completely compensated and NO calculations are necessary by the user. Compensation is accomplished by a special winding "A" on the internal current transformer which opposes the normal LOAD CURRENT flux by the current flowing in the potential circuit. This reduces the wattmeter reading by the amount of power lost in the potential circuit and therefore the VOLT-AMP-WATTMETER indicates true load WATTS.

All non-compensated wattmeters read high by the power consumed in the usual wattmeter potential circuit or the power lost in the current circuit, depending upon the connections used. See figure 1 below.

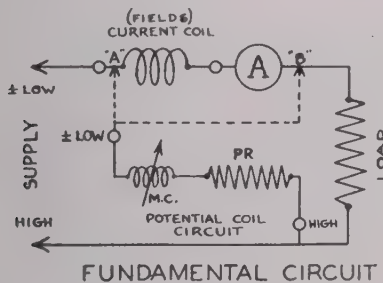


Figure 1

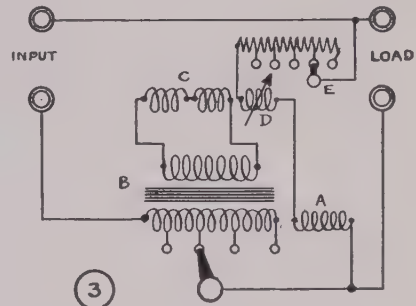
Wattmeters are usually connected to the supply line and to the load, as shown in figure 1. The end of the potential coil can be joined to either "A" or "B." REGARDLESS of which connection is chosen, the wattmeter will read HIGH by the power consumed in either the potential coil circuit or by the power consumed in the current coil and ammeter—depending on whether the "A" or "B" connection is used. The wattmeter will NEVER read high by the power consumed in BOTH circuit elements.

If connected to "A," the wattmeter reads load power plus I^2R loss in current coils and ammeter. If connected to "B," the wattmeter reads load power plus $\frac{E^2}{R}$ loss in potential coil circuit.

In the usual non-compensated wattmeter it is therefore necessary to calculate the losses in watts and subtract this value from the reading, for accurate results.

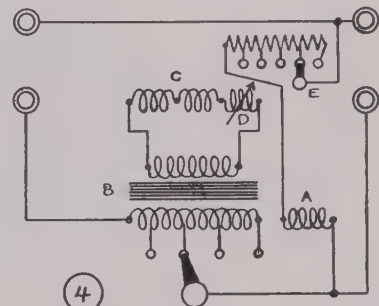
In this VOLT-AMP-WATTMETER we use the "B" connection and internally compensate for the potential circuit losses.

The internal instrument circuit is so designed that in measuring the VOLTS or AMPERES of the load being measured, the operation of the selector switch DOES NOT affect the load and supply circuits whatsoever. See figures 3, 4 and 5.



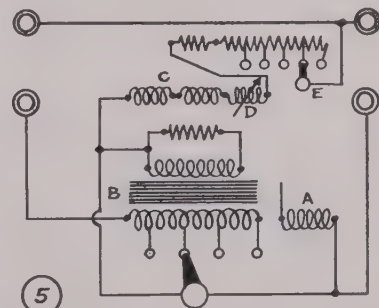
INTERNAL CIRCUIT WHEN MEASURING WATTS

- A—Compensating Winding
- B—Instrument Current Transformer
- C—Dynamometer Field Coils
- D—Dynamometer Moving Coil
- E—Potential Circuit Resistances



INTERNAL CIRCUIT WHEN MEASURING LOAD CURRENT

Note: Potential circuit is still connected across load, but its current drain is NOT included in ampere reading.



INTERNAL CIRCUIT WHEN MEASURING LOAD VOLTAGE

Note: Instrument transformer is still connected in the Circuit.

All the above circuits are controlled by internal switching which action will not cause errors in any measurement.

Continued next page

VOLT-AMP-WATTMETERS

MODEL VAW

ACCURACY	See below
SCALE	5.2"
FREQUENCY	Up to 800 Cycles
SIZE	13¼"x7½"x6½"
WEIGHT	12 lbs.
TYPE	Dynamometer

**HORIZONTAL
USE ONLY**

**INSTRUMENT
TRANSFORMER COUPLED
DYNAMOMETER
MOVEMENT**

***FOR USE FROM
50 TO 800 CYCLES!**

**FORMICA CASES
AVAILABLE
(See Page 116)**

ACCURACY
.5 of 1% for Volts and Amperes
.75 of 1% for Watts

This VOLT-AMP-WATTMETER is quite readily used as a separate DYNAMOMETER VOLTMETER at frequencies from 50 to 133 cycles having ranges of 0-25/50/100/200/500 Volts (internal resistance 100 ohms per volt, current drain 10 milliamperes). The lowest calibrated scale point is 5 volts.

It will also indicate correctly on D.C. volts from 100 to 500 volts without corrections.

To use, simply set the circuit selector switch on VOLTS and use the COMMON and separate VOLT binding posts. Ranges are obtained by the use of the selector switch.

DYNAMOMETER AMMETER

This instrument can be used as a transformer coupled dynamometer 50 to 800 cycle A.C. Ammeter, having ranges of .5/1/5/10 amperes. (Lowest calibrated point is 100 milliamperes.)

It cannot be used, however, on direct currents.

To use, set the circuit selector switch on AMPERES and connect the COMMON and the separate AMPERE binding posts to the circuit.

MAGNETICALLY SHIELDED



WATTMETER OPERATION

The external connectors are simple. See fig. 2. Set the voltage range selector switch, to the nearest voltage range of the supply voltage. As the load is usually approximately known, set the current range selector to the nearest current range. Place the circuit selector switch on VOLTS. Turn on the supply. Read VOLTS. Place the circuit selector switch on CURRENT. Read AMPERES. Turn circuit selector switch to WATTS. Read WATTS. (This will be the true watts of the load, as the wattmeter is internally compensated for any of its losses.)

D.C. watts cannot be measured.

All of the above measurements can be completed in a very few moments without changing any connections nor does the load on the power supply change for any range or for any position of the V-A-W switch.

The power factor of the load can be readily calculated by

$$P. F. = \frac{\text{Watt Reading}}{\text{Volts x Amperes}}$$

*The instrument can be used down to Power Factors of 50% at 25-125 cycles at full accuracy, at 400 cycles 50% P.F. accuracy is 1½%, at 800 cycles, 50% P.F. accuracy is 3%, for 100% P.F., full accuracy to 800 cycles.

VOLT-AMP-WATTMETERS

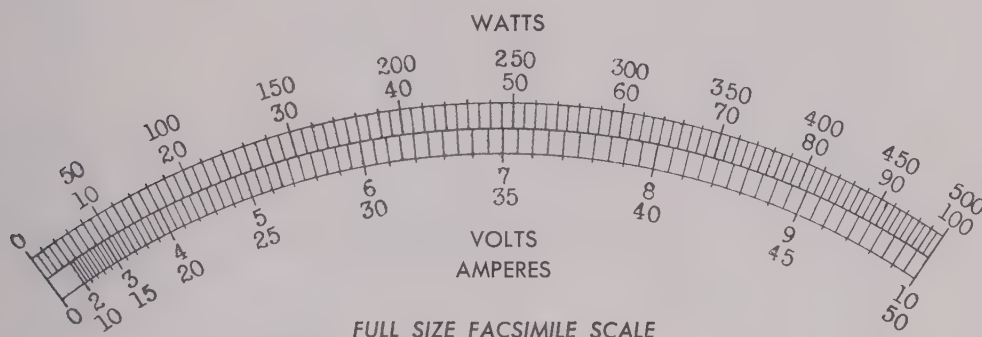
Our VOLT-AMP-WATTMETER has an accuracy of .75 of 1% on WATTS; on VOLTS and AMPERES .5 of 1%. Its scale length of 5.2 inches is very easily read. It is supplied in an American Walnut case with chrome plated fittings; dimensions 13¾" x 7½" x 6½".

This is a beautiful appearing instrument with a black

moulded bakelite panel.

The purchaser can be assured of being pleased with this instrument's action and accuracy. The price is most reasonable considering that this one instrument replaces 3 instruments which total cost would be approximately *\$1400.00.

*Taken from various manufacturer's catalogs.



In many cases it is not necessary for an instrument to measure accurately up to 800 cycles. We are therefore

listing two combinations of ranges, one for frequencies up to 133 cycles and the other for frequencies up to 800 cycles.

STANDARD VOLT-AMP-WATTMETER

Frequency from 50 to 133 cycles

VOLTS	Lowest Reading
25.....	5 volts
50.....	10 volts
100.....	20 volts
200.....	40 volts
500.....	100 volts

(Resistance 100 ohms per volt)

AMPERES	Lowest Reading
.5.....	100 Milliamperes
1.0.....	200 Milliamperes
5.0.....	1 Ampere
10.0.....	2 Amperes

WATTS	Lowest Reading
12.5.....	.125 watt
25.0.....	.25 watt
50.0.....	.5 watt
100.0.....	1.0 watt
125.0.....	1.25 watts
200.0.....	2.0 watts

5 Ranges of VOLTS
4 Ranges of CURRENT
12 Ranges of WATTS

250.0.....	2.5 watts
500.0.....	5.0 watts
1000.0.....	10.0 watts
2000.0.....	20.0 watts
2500.0.....	25.0 watts
5000.0.....	50.0 watts

Code VOLTAWATT Price \$405.00

SPECIAL VOLT-AMP-WATTMETER

When this VOLT-AMP-WATTMETER is supplied for use from 50 to 800 cycles, the following ranges only are supplied:

Frequency from 50 to 800 cycles

VOLTS	Lowest Reading
100.....	20 volts
200.....	40 volts
500.....	100 volts

AMPERES	Lowest Reading
.5.....	100 Milliamperes
1.0.....	200 Milliamperes
5.0.....	1 Ampere
10.0.....	2 Amperes

3 Ranges of VOLTS
4 Ranges of CURRENT
9 Ranges of WATTS

WATTS	Lowest Reading
50.....	.5 watt
100.....	1.0 watt
200.....	2.0 watts
250.....	2.5 watts
500.....	5.0 watts

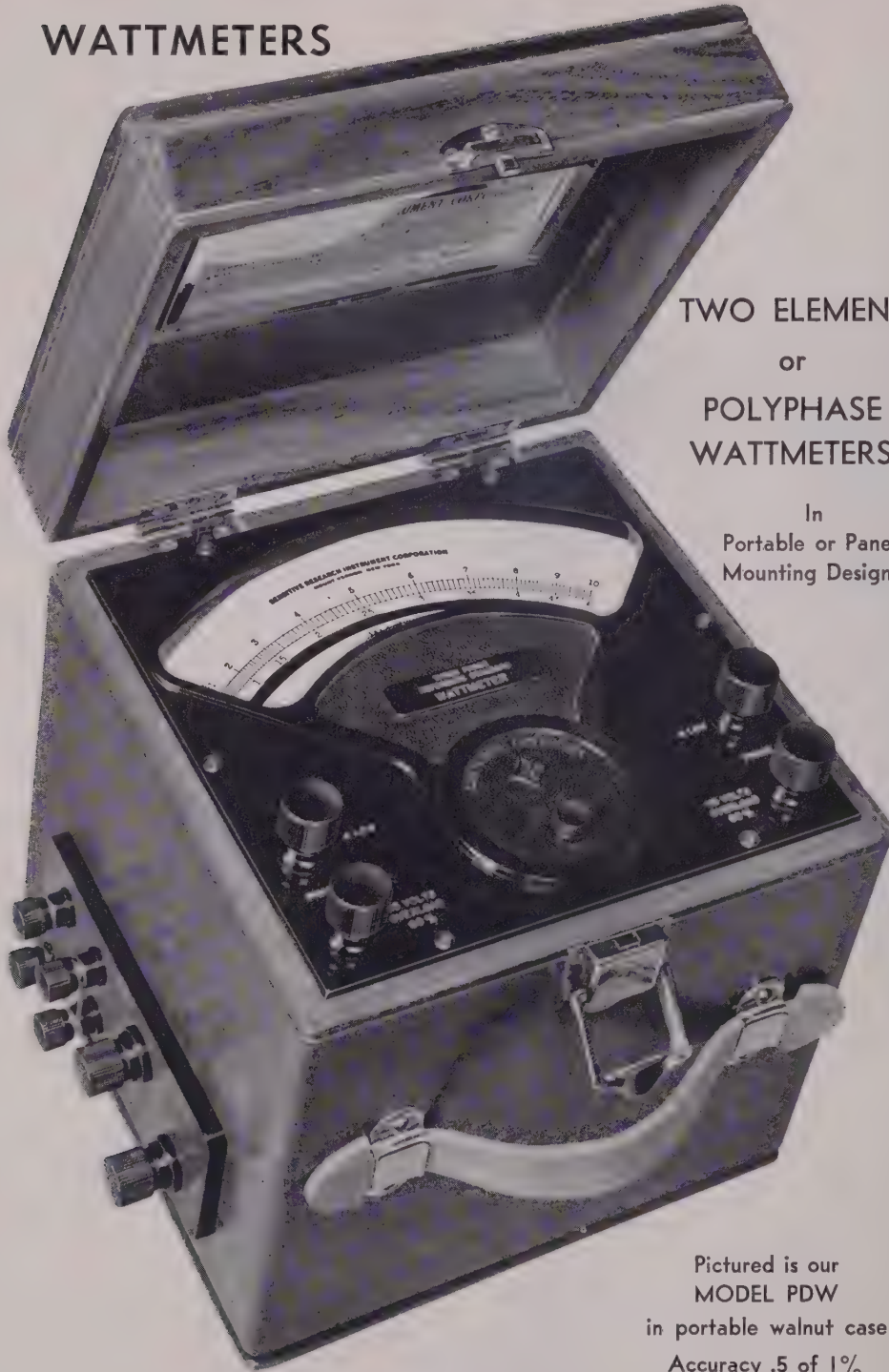
1000.....	10.0 watts
2000.....	20.0 watts
2500.....	25.0 watts
5000.....	50.0 watts

Code VOLTOWATT Price \$430.00

The utility and general economy of the Volt-Amp-Wattmeter makes it a MUST in any progressive laboratory. SENSITIVE RESEARCH instruments are unconditionally guaranteed as to workmanship and materials for a

period of one year. We guarantee our instruments to maintain their described accuracies, provided they are NOT ABUSED and that the instrument seal is not broken.

POLYPHASE WATTMETERS



TWO ELEMENT
or
POLYPHASE
WATTMETERS

In
Portable or Panel
Mounting Designs

Pictured is our
MODEL PDW
in portable walnut case

Accuracy .5 of 1%
Scale length 6.3"

FORMICA CASES
AVAILABLE

MODEL PDW

TWO ELEMENT WATTMETER

ACCURACY	See below
SCALE	6.3"
FREQUENCY	Up to 800 Cycles
SIZE	8"x7 1/2"x6"
WEIGHT	7 lbs.
TYPE	Dynamometer

HORIZONTAL USE ONLY

The commonly accepted definition of polyphase power is that "if energy is supplied to a network through 'n' number of wires, the total power of the system is given by the algebraic sum of the readings of 'n' number of wattmeters so arranged that each one of the 'n' wires contains one current coil; the corresponding wattmeter potential coil is connected between that wire and some point common to all of the potential circuits." This then is the general definition of polyphase power.

This being a general definition, we can make a further assumption that this common point from which all potentials are measured can be upon one of the 'n' number of wires. This, of course, means that the potential between the common point and this wire is zero and that, therefore, one of the aforementioned 'n' number of wattmeters would read zero. From this we see that for any polyphase system of 'n' number of phases, the total power in the system can be read by 'n' minus 1 wattmeters. This is commonly known as Blondell's Theorem.

Mathematical proof of this is given below:

Let the supply conductors be denoted by the subscripts 1, 2, 3, . . . , N, let the instantaneous voltages of the load be denoted by $V_1, V_2, V_3, \dots, V_N$ and the instantaneous currents at these same points be $I_1, I_2, I_3, \dots, I_N$.

Then the current through wire 1 will be I_1 and the instantaneous power delivered through conductor 1 will be $I_1 V_1$, and similarly for all the other conductors. Therefore:

$$P = I_1 V_1 + I_2 V_2 + I_3 V_3 + \dots + I_N V_N \quad (1)$$

Now let V_0 be the potential of any designated point on the system.

According to Kirchoff's Law:

$$I_1 + I_2 + I_3 + \dots + I_N = 0 \quad (2)$$

Hence:

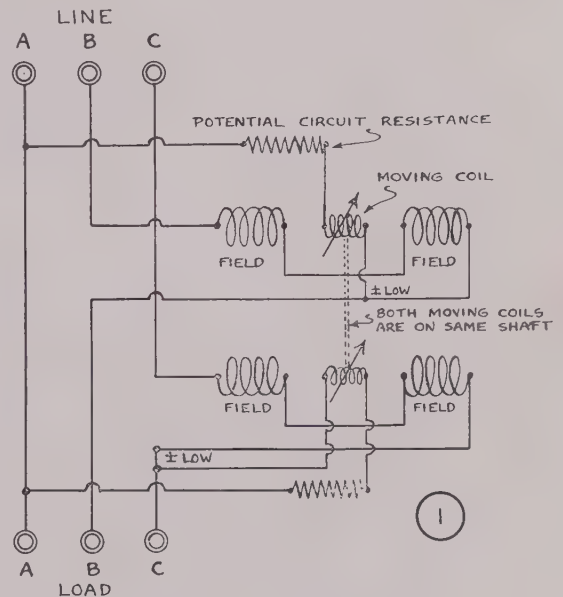
$$I_1 V_0 + I_2 V_0 + I_3 V_0 + \dots + I_N V_0 = 0 \quad (3)$$

Subtracting (3) from (1):

$$P = I_1 (V_1 - V_0) + I_2 (V_2 - V_0) + \dots + I_N (V_N - V_0)$$

The measurement of polyphase power is somewhat more difficult than the simple measurement of single phase power. When we speak of polyphase power, we mean the total power delivered to a given polyphase load by all 3, 4 or more number of lines used to feed the load.

Inasmuch as the voltages and currents on the various lines could have widely varying phase characteristics, we have to adopt a standard definition of the power involved. It should be a definition which would agree with, for instance, a calorimetric measurement of this power.



TWO ELEMENT WATTMETER
Connections for 3 Phase 3 Wire Circuits

From this the average power will be:

$$P = \frac{1}{T} \int_0^T I_1 (V_1 - V_0) dt + \frac{1}{T} \int_0^T I_2 (V_2 - V_0) dt + \dots + \frac{1}{T} \int_0^T I_N (V_N - V_0) dt \quad (4)$$

However:

$$\frac{1}{T} \int_0^T I_1 (V_1 - V_0) dt \text{ is the reading of wattmeter}$$

in conductor 1 and similarly for the other terms of the expression and (4) is the summation of the N wattmeter readings.

If now the common potential V is taken to be on one of the N wires then one of the power quantities is parenthesis will be zero, the corresponding wattmeter reads zero and $N - 1$ wattmeters are required.

Let us now take our general polyphase condition and limit it to 3 phase. This is the commonest commercial polyphase power with which one generally has to work. Blondell's Theorem above, having shown that we can measure the power in any polphase circuit with $n-1$ number of wattmeters, it follows that in our 3 phase 3 wire circuit, the power can then be measured by 2 wattmeters.

In Figure 1, as shown, the connection diagram for 2 wattmeters to measure the total power in the load fed by the 3 phase line A, B, C, therefore, the sum of the 2 wattmeters is then equal to the total power being delivered to this load.

As most loads are either balanced or at least somewhere near balanced, it will be seen that the 2 wattmeters used would, in general, be on the same range. If these 2 wattmeter moving coils were then mounted on a single shaft, their torques could be added mechanically and the scale suitably calibrated to give a direct addition of the quantity being measured by each instrument.

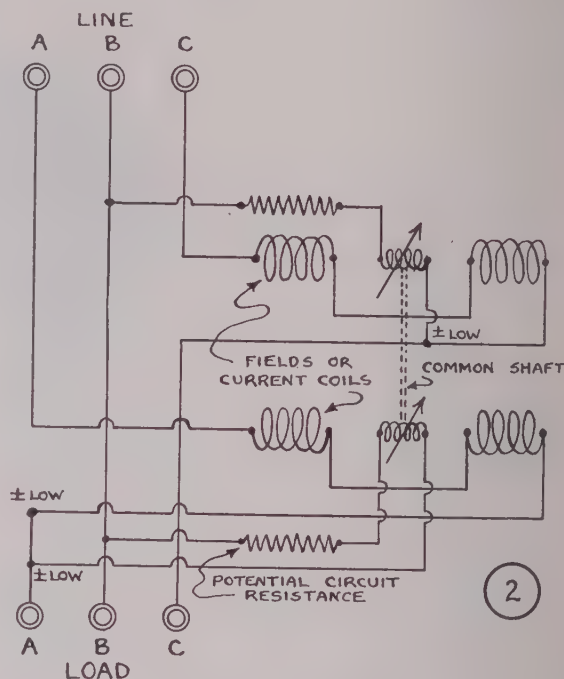
This is shown by the dotted line in Figure 1, which represents a mechanical coupling between the moving coils of the 2 instruments. This assembly is commonly called a 3 phase wattmeter, but somewhat more properly called a 2 element wattmeter, because it has many uses besides that of merely the measurement of 3 phase power.

The actual mechanical production of such an instrument demands instrument skill of the highest order, because it is first necessary to have 2 instruments whose characteristics are identical. They must be capable of using a common scale throughout their entire range and match this scale well within the established percentage of accuracy. To do this, they must be very accurately aligned on a common shaft. The added weight of the two movements, actually more than double because of the necessary couplings and fittings, makes a very heavy torque to weight ratio for the instrument and demands the maximum of skill to produce an acceptable instrument. Its construction is further complicated by the requirement that neither instrument have the slightest reaction upon the other movement, even though they are physically located adjacent to each other on a common shaft. The SENSITIVE RESEARCH 3 Phase Wattmeter illustrated in this bulletin meets all of these requirements to the greatest degree of accuracy.

Our portable 3 phase (2 element) wattmeter is supplied in a walnut case with removable cover. The case is $8\frac{1}{2}$ " high, $7\frac{3}{4}$ " long and $7\frac{1}{2}$ " wide. Its scale length is $6\frac{3}{8}$ " and its overall accuracy is .75 of 1% or .5 of 1%, depending on the power factor range of the instrument chosen.

OTHER USES

The 3 phase wattmeter herein described has other usages besides that of simply the measurement of 3 phase power. It has a very worthwhile use in single phase work where 3 wire lines are used and the load may or may not be completely balanced.



TWO ELEMENT WATTMETER
Connections for Single Phase 3 Wire Circuits

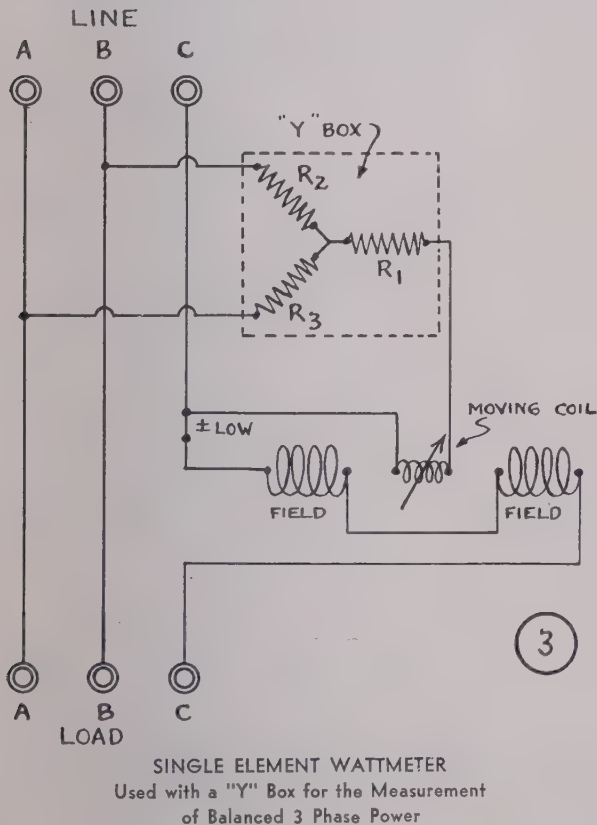
The use of the 2 element wattmeter (also called 3 phase) in this case, is shown in Figure 2, where it indicates correctly the entire load on the line regardless of whether it is on either one of the low voltage circuits or is bridged across the 2 outside or high voltage pairs. Further, if desired the 2 element wattmeter can be used where the sum of the power in any 2 lines may be required, such as 2 single phase lines. The 2 portions of the movement are completely isolated and can be used in 2 entirely different circuits, in which case, the instrument will measure the algebraic product of the power being consumed in the 2 circuits. Further, the 3 phase wattmeter (also called 2 element) can be used as a simple single phase wattmeter by either one of two methods. A single half of the movement can be used as a single phase wattmeter, in which case the scale readings will give the correct power in the circuit. If, however, the two current sections of the wattmeter are connected in series, the 2 potential coils connected in parallel and the instrument used as a single phase wattmeter, the scale readings will need to be divided by two.

SPECIAL CASES

Other sections of this bulletin have described the measurement of 3 phase power, in which case the load may be completely unbalanced, balanced, or approximately balanced and the instrument will still give perfectly corrected indications. Let us now go into a little further investigation of the specialized condition in which the power is exactly balanced on all 3 phases of the line.

In this special case of a completely balanced load, and by balanced we mean that the voltage on each of the 3 phases and the current on each of the 3 phases are identical.

In this specialized condition of balanced power there are several methods by which the entire load power can be measured satisfactorily with a single phase wattmeter, combined with other accessories such as current transformers or a Y box. The simplest and most acceptable of these is the use of the Y box shown in Figure 3.



This is an accessory which can be supplied with any of our standard wattmeters and will allow the measurement of 3 phase power.

The Y box as normally furnished, consists of a pair of resistors accurately matched to each other and to the total resistance of the potential circuit in the wattmeter

with which it is to be used. These 2 series resistors have the extremes attached to 2 of the 3 wires feeding the load.

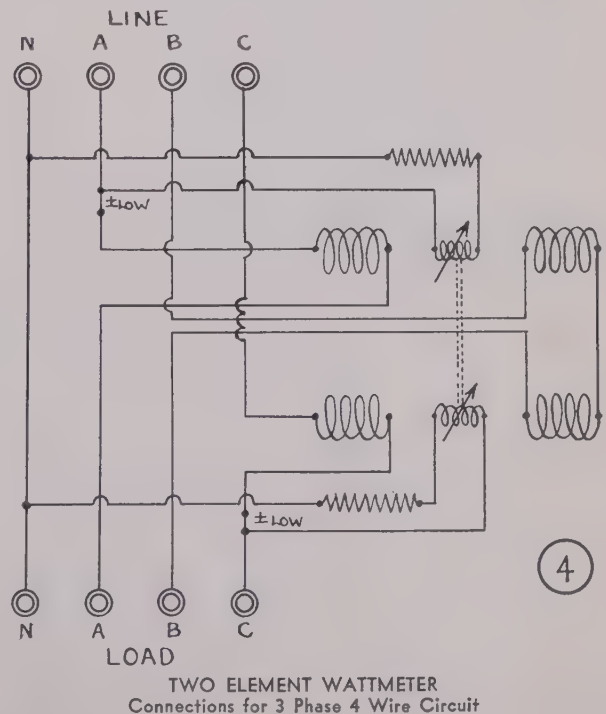
The center tap is connected to the normal potential circuit of the instrument with the low side grounded on the third leg, which also contains the current circuit of the wattmeter. Under these conditions the wattmeter reading, multiplied by 3, will be identical with total load in the 3 phase circuit.

In the use of the Y box it should always be remembered that the readings will be correct in terms of 3 phase power only in those cases where the load is exactly balanced.

Y boxes can be furnished either with your order for single phase wattmeters, or by supplying us with the serial number of the instrument, they can be furnished for wattmeters already in the field. It is necessary, however, that the individual Y box be matched to the instrument with which it is to be used. If the Y box is to be used with more than one instrument, a correction factor will in general be necessary when using with instruments other than that for which it is calibrated.

USE OF 2 ELEMENT WATTMETER ON 4 WIRE 3 PHASE CIRCUITS

A specialized case for the use of the 2 element, 3 phase wattmeter, which is very frequently encountered, is that for the measurement of total power in a 4 wire, 3 phase circuit. The connections to accomplish this type of measurement are shown in Figure 4 and the results of such measurements are usually commercially satisfactory.



POLYPHASE WATTMETERS

From Blondell's Theorem, mentioned earlier in the discussion, it would seem that it would be necessary to have 3 wattmeters for the measurement of total power in the 4 wire, 3 phase lines. If all possible combinations of unbalanced lines were to be considered, this would, of necessity, be true.

However, a reasonable commercial measurement can ordinarily be made with the connections shown in Figure 4. The measurements using this circuit have one condition. They pre-suppose that the voltages only for the 3 phases will be balanced. As this is a condition which is normally encountered in practice, the total error of measurement is very slight.

The connections shown allow for unbalanced current but will be in error if the voltages are seriously unbalanced. This ordinarily occurs only at the end of very long 3 phase lines or where power supply is rather inadequate. These are conditions which are not too frequently encountered and usage of the instrument in this fashion is very widespread.

A polyphase wattmeter must be correctly connected to make power measurements, which means that the polarity markings must be followed exactly. Be sure to connect the instrument so that as the current comes from its supply that it enters both the current and voltage circuits of the wattmeter at the engraved ($\pm$ LOW) binding posts.

MODEL PDW

POLYPHASE OR TWO ELEMENT WATTMETERS

ACCURACY	.5 of 1%
SCALE	6.3"
FREQUENCY	To 800 cycles
SIZE	8"x7½"x6"
WEIGHT	7 lbs.
TYPE	Dynamometer

HORIZONTAL

Listed below are standard ranges for Polyphase (two element) wattmeters. ANY polyphase instrument will indicate full scale for ANY of these combinations of rated power.

1. Three phase power in any combination of loading, balanced or unbalanced.
2. Single phase power applied to EITHER phase A circuits OR phase B circuits, not both.
3. The SUM of single phase powers being fed to phase A and phase B circuits simultaneously.
4. Two phase power fed to phase A and phase B circuits.

SUPPLIED WITH DIAMOND PIVOTS
AND SHOCK MOUNTED JEWELS

THREE RANGE

FULL SCALE WATTS		NORMAL (Unity P. F.) FIELD CURRENT		MAXIMUM (50% P.F.) FIELD CURRENT		(OVERLOAD 60%) VOLTS		Code Word	Price
Low Volts	High Volts	Series	Parallel	Series	Parallel	Low	High		
15/30	30/60	.075 A.	.15 A.	.15 A.	.3 A.	100	200	PDWAMIS	\$550.00
25/50	50/100	.125	.25	.25	.5	100	200	PDWANOT	550.00
37.5/75	75/150	.1875	.375	.375	.75	100	200	PDWYFAT	550.00
75/150	150/300	.375	.75	.75	1.5	100	200	PDWASUL	550.00
125/250	250/500	.625	1.25	1.25	2.5	100	200	PDWARAB	550.00
150/300	300/600	.75	1.5	1.5	3.0	100	200	PDWHACK	565.00
250/500	500/1000	1.25	2.5	2.5	5.0	100	200	PDWASED	570.00
300/600	600/1.2 k.w.	1.5	3.0	3.0	6.0	100	200	PDWAHLN	570.00

Potential circuits vary from 100 to 333 ohms per volt.

The lower watt instruments require a 10 milliamperere potential circuit current.

FOUR RANGE WATTMETER

FULL SCALE WATTS			NORMAL FIELD CURRENT		MAXIMUM FIELD CURRENT		(OVERLOAD 60%) VOLTS			Code Word	Price
Low Volts	Medium Volts	High Volts					Low	Medium	High		
15/30	30/60	60/120	.15 A.	.3 A.	.3 A.	.6 A.	50	100	200	PDWEAPA	\$565.00
25/50	50/100	100/200	.25	.5	.5	1.0	50	100	200	PDWEALM	565.00
50/100	100/200	200/400	.5	1.0	1.0	2.0	50	100	200	PDWEAZO	565.00
75/150	150/300	300/600	.75	1.5	1.5	3.0	50	100	200	PDWEAEN	580.00
125/250	250/500	500/1000	1.25	2.5	2.5	5.0	50	100	200	PDWEAFE	585.00
250/500	500/1000	1000/2000	2.5	5.0	5.0	10.0	50	100	200	PDWEAGZ	585.00

NOTE:—All the above ranges can be supplied but with the voltages increased to

110 220 440

Use the
above code
word adding
the letter
"S"

Prices
same
as
above
ranges

Our POLYPHASE WATTMETERS are also supplied in an edgewise panel mounted case (see pictures next page). This cast aluminum case is called PDWEW-5 and its scale length is 5.2", the same as the portable Model PDW. The addition of the letters EW to PDW means supplied in an edgewise wall case. Add \$50 to price.

PLEASE NOTE: MODEL PDLW—Low power factor type polyphase wattmeters are available. Correspondence invited. Power factor 20%. Accuracy .75 of 1% and scale 5.2".

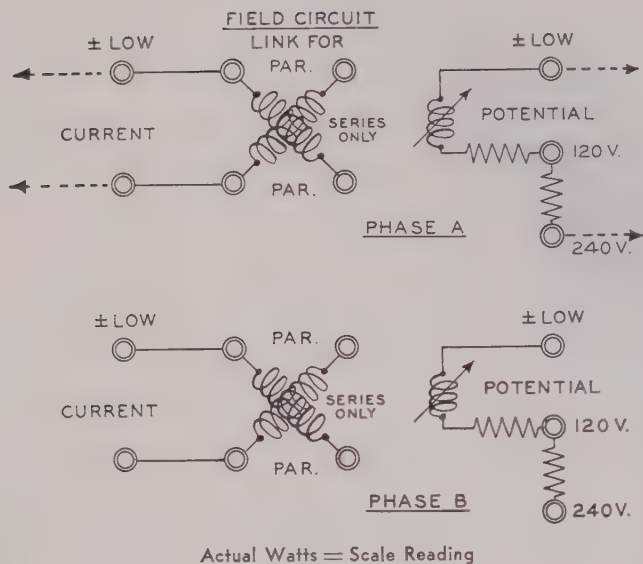
A large, dark, rectangular metal component, likely a transformer or power supply unit, with a label on the front face. The label contains the following text: "WATTS", "DOWN TO 1/2", "SERIAL NO. 1000000000", "NO. 1000000000", "SERIAL NO. 1000000000", "NO. 1000000000", "SERIAL NO. 1000000000", "NO. 1000000000". The component has a curved front face and a flat top face. The label is white with black text. The component is mounted on a base with four screws.

CURRENT PHASE A
 PHASE A FIELD CIRCUIT PAR.
 SERIES ONLY
 SEL. FIELD-120V. 900W. 375A.
 SER. - 240V. 1500W.
 PAR. FOR 60-120V. 1500W.
 PAR. - 240V. 1500W.
 PHASE B
 PHASE B FIELD CIRCUIT PAR.
 SERIES ONLY
 SEL. FIELD-120V. 900W. 375A.
 SER. - 240V. 1500W.
 PAR. FOR 60-120V. 1500W.
 PAR. - 240V. 1500W.
 PAR.



POLYPHASE WATTMETER CONNECTIONS

CONNECTIONS FOR USE ON SINGLE PHASE



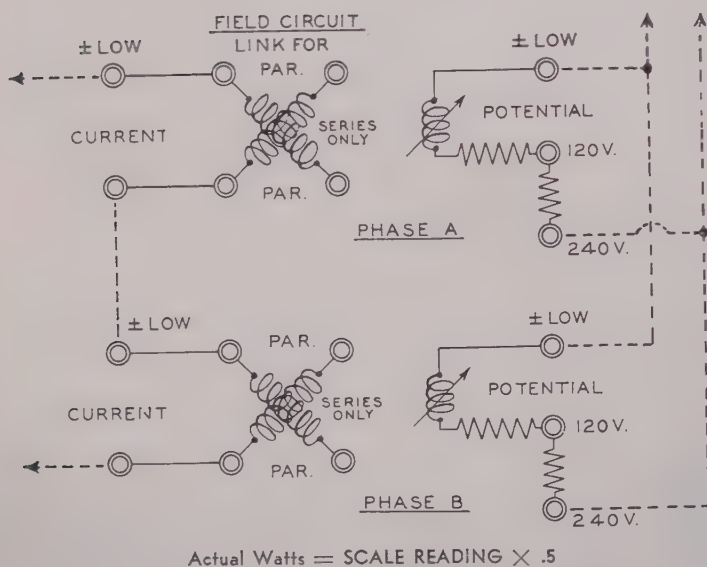
Any "SENSITIVE RESEARCH" POLYPHASE Wattmeter can be readily used for single phase measurements.

The circuit on the left shows the usual single phase connectons. Either Phase A OR phase B can be used by itself alone — NOT BOTH.

The actual watts will be the actual instru-ment scale reading.

The dotted lines on the circuit show the external circuit connections. The solid lines are the internal connections of the POLYPHASE WATTMETER.

CONNECTIONS FOR SINGLE PHASE MEASUREMENTS THAT WILL DOUBLE THE SENSITIVITY OF THE WATTMETER!



A POLYPHASE WATTMETER can be con-nected for single phase use in such a way that its basic full scale sensitivity CAN BE DOUBLED.

Connect the current circuits of Phase A and Phase B (field coils) in series and the two poten-tial circuits in PARALLEL. (See circuit on left).

Multiply the pointer indicated scale reading by .5

Example: Assume a full scale deflection

Full scale printed WATTS = 1200

Actual WATTS is 1200 x .5 = 600 Watts

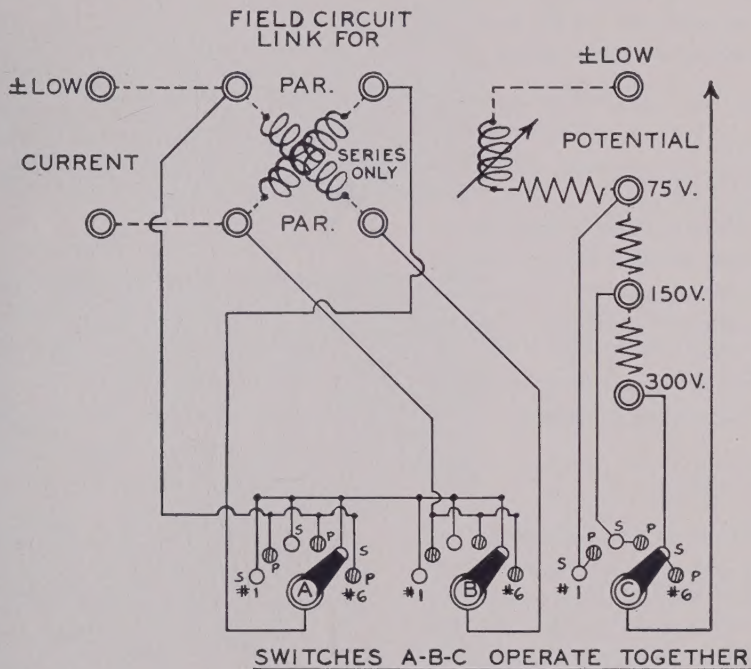
SINGLE PHASE WATTMETER CONNECTIONS

WATTMETER SWITCHING

A large portion of our total wattmeter sales are of our PANEL MOUNTING design (our type EW-5 and EW-7 cases, see page 87).

Unlike a portable cased wattmeter (Models DW & DLW) whose binding posts are readily accessible, a panel mounted wattmeter has its connections at the rear of its case.

A number of requests have been received for details on wattmeter switching. Shown below is a typical circuit for such switching using a three pole range selector switch (dotted lines show internal connections).



○ — SERIES FIELD CONNECTION
 ● — PARALLEL " "

TYPICAL SINGLE PHASE WATTMETER CIRCUIT USING EXTERNAL SWITCHING

Assume

the circuit shown above is for a 75—150—300—600 Watt instrument
 With voltage ranges of 75—150—300 Volts
 And normal current range of 1 and 2 amperes at Unity P.F.

Then the ranges using the above switching would be

#1 position	SERIES FIELDS	— 75 Volts = 75 Watts
#2 position	PARALLEL FIELDS	— 75 Volts = 150 Watts
#3 position	SERIES FIELDS	— 150 Volts = 150 Watts
#4 position	PARALLEL FIELDS	— 150 Volts = 300 Watts
#5 position	SERIES FIELDS	— 300 Volts = 300 Watts
#6 position	PARALLEL FIELDS	— 300 Volts = 600 Watts

Normal current	— series fields	— 1 Ampere
Maximum current	— series fields	— 2 Amperes (50% P.F. instrument)
Maximum current	— series fields	— 5 Amperes (20% P.F. instrument)
Normal current	— parallel fields	— 2 Amperes
Maximum current	— parallel fields	— 4 Amperes (50% P.F. instrument)
Maximum current	— parallel fields	— 10 Amperes (20% P.F. instrument)

NOTES ON WATTMETER CALIBRATION

The calibration of wattmeters to HIGH ACCURACIES and low power factors is considerably more difficult than a superficial examination brings to light. The usual laboratory check by most meter calibration departments consists in using two separate D.C. sources.

One D.C. source supplies the calibrated potential for the moving coil circuit, and a second source furnishes a calibrated D.C. current to the field coils. Such a calibration will allow a check of the wattmeter to the accuracy of the D.C. measurements of current and voltage.

For checking D.C. watts, the above test would be perfectly true and correct. When we attempt to check a Wattmeter's A.C. accuracy, we encounter difficulties. The true wattmeter reading is of course, $E I \cos \theta$ and we need to set up equally accurate currents and voltages on the A.C. basis. In addition, we must know accurately the phase angle between the voltage and current. For accuracies of 1% or 2%, this is not a difficult condition to fulfill. For accuracies of the LABORATORY STANDARD, .1 of 1% class instrument, it becomes an extremely difficult condition to fulfill for all test conditions.

UNITY POWER FACTOR (100%)

At 100% power factor, if we can set up a voltage and current with the necessary accuracy and measure zero phase angle to an accuracy of only 1.5 degrees, we have .05% possible error from the $\cos \theta$ function. We can easily hold the actual values of voltage and current to .05% absolute error of magnitude. These combinations allow a total calibration accuracy of .1% and this accuracy of phase angle measurement is not too difficult to achieve.

50% POWER FACTOR CALIBRATION

Now to check the same instrument for accuracy at 50% power factor, we use the same sort of calibration technique except we shift the phase of the current 60° to simulate a 50% power factor load. Under these conditions, we find that an error of phase angle measurement of only 2 minutes can be tolerated for .05% error instead of 1.5 degrees.

This sort of phase angle measurement becomes extremely difficult. To make phase angle measurements to this sort of accuracy becomes almost impossible under the usual laboratory conditions.

As a matter of fact, even the DEFINITION of phase angle to this accuracy becomes difficult with the usual NEAR SINUSOIDAL source instead of a perfect sinusoid.

This same sensitivity to very slight phase angle errors showing up as of appreciable magnitude at low power factors effects the design of wattmeters. Eddy currents in or near the field coils, capacity or inductive errors in resistors, and incorrect frequency compensation, all show up as light phase angle errors in a wattmeter. This will effect its low power factor calibration markedly though it may be completely negligible in the area of unity power factor loads.

A consequence of this situation is that it is very difficult to set up sufficiently accurate tests for certification of high accuracy (.1 of 1%) wattmeter instruments at power factors below 80% even in a well equipped laboratory.

NOTES OF INTEREST

The National Bureau of Standards has set up an equivalent type of test for such standardization. They have constructed a single very unusual wattmeter with all possible precautions taken to eliminate phase angle errors inherent to the instrument itself.

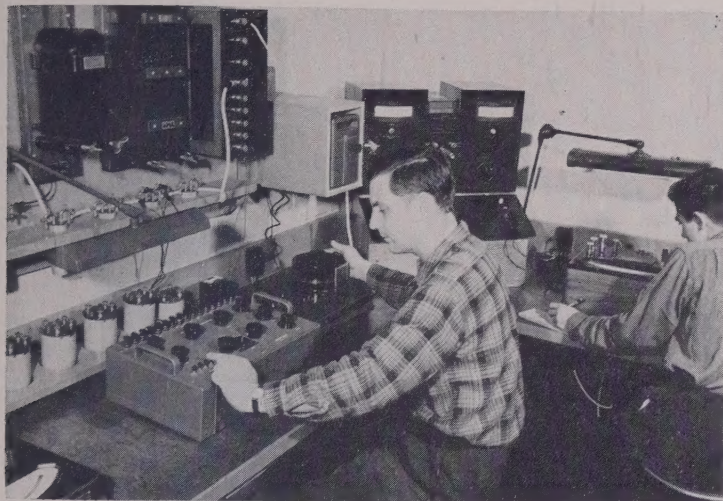
Over the past 15 years, measurements and calculations show this instrument to have negligible phase angle errors. For high accuracy wattmeter standardizations, calibrations are made first on D.C. by standard potentiometer methods. Then the instruments under test and the NBS Wattmeter are compared on D.C. and on A.C. at approximately the specified power factor, with the reasonable assumption that the standard does NOT contribute additional errors in A.C. operation. An "A.C.-D.C. difference" factor is then derived for the desired A.C. operation at any specified power factor.

This type of comparison against an accepted standard is in lieu of the almost impossible to attain measurement directly to these accuracies from primary standards.

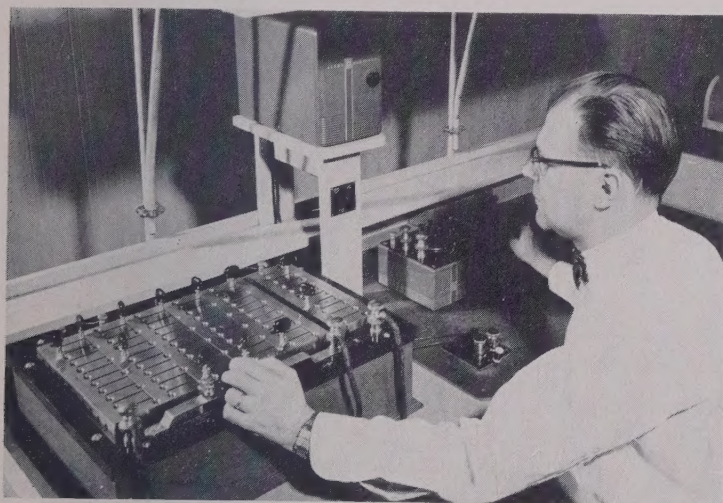
The difficulty involved in employing absolute calibration techniques to the necessary accuracies have led Sensitive Research to discontinue production of .1 of 1% accuracy wattmeters for use on power factors below 80%, for which accuracy guarantees can only be obtained by reference to the national standard in Washington.

Considerable work is going forward in our own laboratories on this problem. We know that other groups are also interested and we hope that industry-wide attention to these difficulties can be expected to produce results in the near future.

We are very interested in power measurements at low power factors and solicit correspondence with our engineering department concerning your problems in which we might assist.



Ranging of Laboratory Standard Wattmeter on direct current using two potentiometers.



Anthony Pattern Bridge and ratio box adjustment of necessary resistances to .025%.



Calibration check of completed Wattmeter on A.C. at different frequency levels using D.C.- A.C. transfer standards.

Before the advent of precise radio time signals, all well found ships carried three chronometers to assure their navigators that his time was correct. Three, because, if he had only one, he would not know if it was fast or slow. If two, then which one was correct?

So three were used—which in normal cases would assure the precise determinations of time.

So it is with "Sensitive Research." We use 2 complete sets of standards from different makers plus our own designs. The case history of each of these have been very carefully watched in the past 30 years.

They have been periodically checked with the National Bureau of Standards. In many cases, the accumulated expense of these certification tests have exceeded the original cost of the standard itself.

The acceptance of standards is a long, time consuming process. For instance, the upper photo shows an outside manufacturers newest potentiometer. It will take a year of our time to accept this standard. Meanwhile, it is being used daily and is checked against a National Bureau of Standard certified potentiometer. When a year has passed, we will definitely know its accuracy cycle, if any.

All our standards are kept in special rooms which in effect, are buildings within our main building. They are completely insulated and have their own thermostatically controlled air supply. The temperature in these rooms does not vary one half degree summer to winter.

To still further maintain our standards, we have constant temperature cabinets in these rooms in which they are kept and only taken out for certification purposes.

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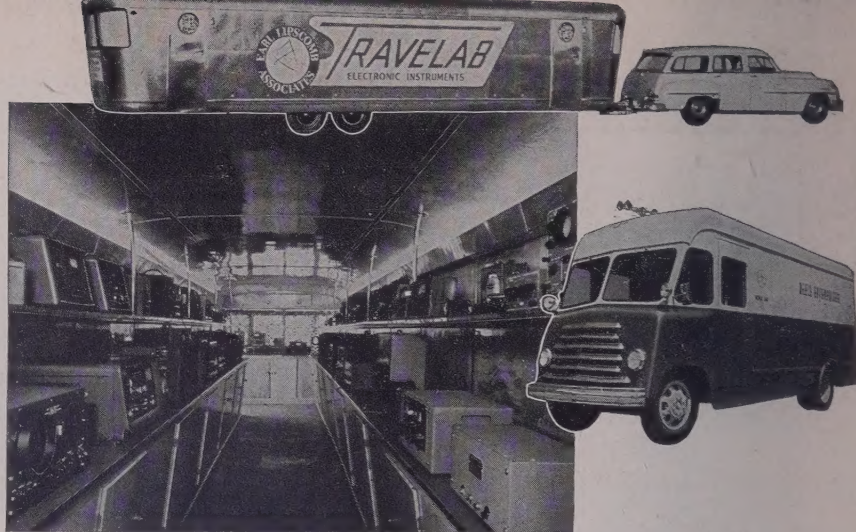
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